

Study of charmonium spectroscopy at BESIII

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In this talk, we will present the results on the charmonium spin singlet states below the open charm threshold, including h_c , η_c , and $\eta_c(2S)$. The masses, widths, and production rates of these states will be reported. The results are based on a data sample of 106 million ψ' events collected with the BESIII experiments at the BEPCII collider.

1 Introduction

In 2009, $(106 \pm 4) \times 10^6$ ψ' events were collected with BESIII detector at the upgraded BEPC (BEPCII) [1]. All the recent results on charmonium spectroscopy reported in this proceeding are based on this set of data.

2 Observation of h_c

In 2010, the results on the production and decay of the h_c at the ψ' resonance was reported by BESIII [2], where the distributions of mass recoiling against a detected π^0 were studied to measure $\psi' \rightarrow \pi^0 h_c$ both inclusively (E1-untagged) and in events tagged as $h_c \rightarrow \gamma \eta_c$ (E1-tagged) by detection of the E1 transition photon. In 2011, 16 specific decay processes of η_c in the decay mode of $h_c \rightarrow \gamma \eta_c$ are studied to do the measurements of the h_c properties in addition. The simultaneous fit of the 16 π^0 recoil-mass spectra (Figure 1) yields $M(h_c) = 3525.31 \pm 0.11 \pm 0.15 \text{ MeV}/c^2$ and $\Gamma(h_c) = 0.70 \pm 0.28 \pm 0.25 \text{ MeV}/c^2$, where the first errors are statistical and the second systematic. These preliminary results are consistent with the previous BESIII inclusive results and CLEO exclusive results ($M(h_c) = 3525.21 \pm 0.27 \pm 0.14 \text{ MeV}/c^2$) [3].

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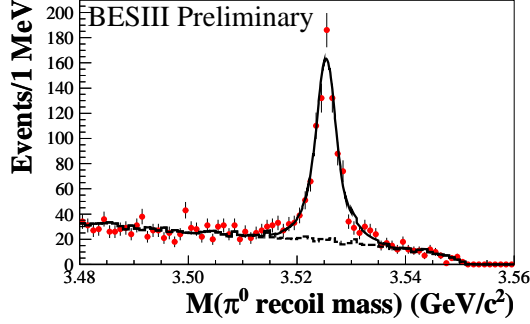


Figure 1: The summed π^0 recoil-mass spectrum of 16 specific decay processes of η_c in the decay mode of $h_c \rightarrow \gamma\eta_c$, where the line is the fit result.

3 Precision measurement of the η_c properties

With the largest ψ' sample collected by BESIII, the η_c mass and width are measured in the radiative transition $\psi' \rightarrow \gamma\eta_c$, where six decay modes of η_c are involved: $K_S^0 K\pi$, $K^+ K^- \pi^0$, $\pi^+ \pi^- \eta$, $K_S^0 K3\pi$, $K^+ K^- \pi^+ \pi^- \pi^0$ and $3(\pi^+ \pi^-)$. A simultaneous fit with the unique η_c mass and width is performed on the η_c mass spectra, where the interference between η_c and non- η_c decays is considered and the quantum number of the non- η_c components are assumed to be 0^{-+} . The corresponding interference phase angles in different decay modes are found to be quite consistent and then set to the same one in final fit. The mass spectra and the simultaneous fit for different decay modes are shown in Figure 2. The obtained results are $M(\eta_c) = 2984.2 \pm 0.6 \pm 0.5 \text{ MeV}/c^2$, $\Gamma(\eta_c) = 31.4 \pm 1.2 \pm 0.6 \text{ MeV}$, and $\phi = 2.41 \pm 0.06 \pm 0.04 \text{ rad}$, where the first errors are statistical and the second systematic. The BESIII preliminary results are consistent with those from two-photon production [4–6], as well as $J/\psi \rightarrow \gamma\eta_c$ by CLEOc [7]. And the precision of the measured mass and width are improved.

4 The first observation of the M1 transition $\psi' \rightarrow \gamma\eta_c(2S)$

BESIII observed this M1 transition $\psi' \rightarrow \gamma\eta_c(2S)$ with the decay mode $\eta_c(2S) \rightarrow K_S K\pi$ for the first time. Figure 3 shows the preliminary result for the invariant mass distribution of $K_S^0 K\pi$ that the three-constraints kinematic fit has been applied (where the energy of the photon is allowed to be floating). The pure statistical significance is more than 6σ . The yielded events number is 50.6 ± 9.7 and $M(\eta_c(2S)) = 3638.5 \pm 2.3 \pm 1.0 \text{ MeV}/c^2$. With the detection efficiency from MC simulation, $B(\psi' \rightarrow \gamma\eta_c(2S) \rightarrow \gamma K_S^0 K\pi) = (2.98 \pm 0.57 \pm 0.48) \times 10^{-6}$ is obtained. Combining the result $B(\eta_c(2S) \rightarrow K\bar{K}\pi) = (1.9 \pm 0.4 \pm 1.1)\%$

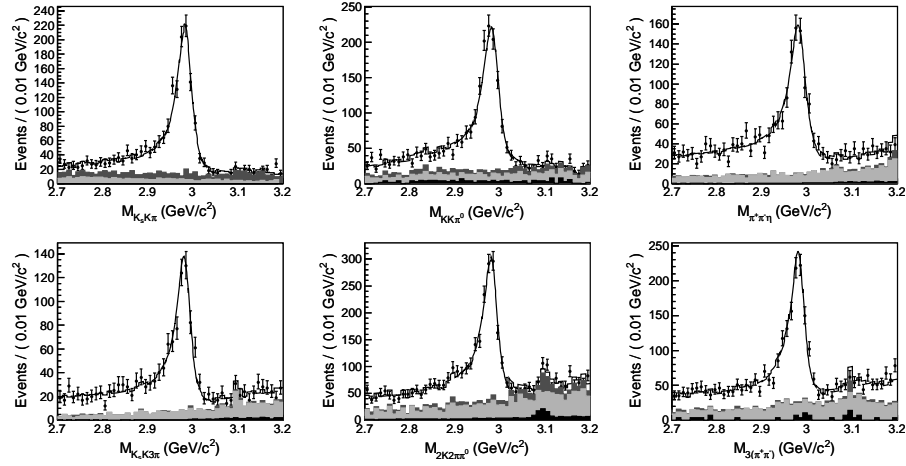


Figure 2: The mass spectra for different decay modes, where the line is the result of the simultaneous fit.

from Babar, it is first calculated that $B(\psi' \rightarrow \gamma \eta_c(2S)) = (4.7 \pm 0.9 \pm 3.0) \times 10^{-4}$ which is consistent with the CLEOc's upper limit [8] and prediction of potential model [9, 10] (the transition rate predicted by [10] should be 4.8×10^{-4} if the mass of $\eta_c(2S)$ is updated to 3637 MeV according to PDG [11]), where the first errors are statistical and the second systematic.

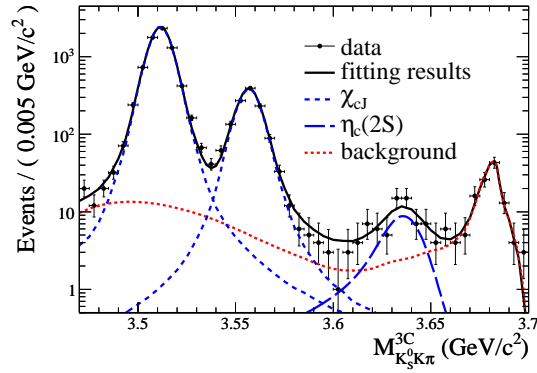


Figure 3: The invariant mass of $K_S^0 K \pi$ from $\psi' \rightarrow \gamma K_S^0 K \pi$.

5 Summary

With the largest ψ' data collected by BESIII, the following results on Charmonium spectroscopy are obtained: the properties of h_c are measured with inclusive and exclusive methods respectively; the properties of η_c are precisely measured using the radiative decays of ψ' , where the interference between η_c decays and non- η_c decays is taken into account; the M1 transition $\psi' \rightarrow \gamma\eta_c(2S)$ is observed for the first time.

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